## REMARKS

Claims 1-4, 6, 7 and 20 are pending in the application and are rejected. Claim 1 is herein amended. Claim 2 is canceled.

**Claim Rejections under 35 U.S.C. §103**

Claims 1-4, 6, 7 and 20 are rejected under 35 U.S.C. §103(a) as being unpatentable over Imai et al. (U.S. 5,001,452) in view of Imai et al. (JP 01-103994) along with Jin et al. (U.S. 5,977,697).

Applicants herein amend claim 1 to provide clarification, and cancel claim 2. Subsequently, Applicants respectfully disagree with the rejection, because one skilled in the art at the time of the invention would not have combined the teachings to reach every limitation of the invention. Moreover, even if one skilled in the art at the time of the invention would have combined the teachings as asserted, the present inventors provide evidence of unexpected results associated with the presently claimed invention.

Applicants submit herewith an Inventor's Declaration that contains supplementary data proving that a substrate surface can be obtained in which steps of each monoatomic layer are arranged in series by polishing a diamond (100) substrate of the present application in the range of 1.5 to 6 degrees, and treating the substrate with hydrogen plasma. The results also explain that the diamond thin film growth takes place by using this substrate by step flow growth mechanism which could not be realized by prior arts, and therefore the S-doped n-type diamond of the present application has the crystal perfectness that could not be realized by the cited references.

As is shown in Fig. 1(a) of the supplementary data, the surface that was only tilted and polished has the roughness of about 20 nm. This result agrees with the result of surface roughness of diamond thin film after growth of Table 1 in the reference Imai et al (JP '994). On the other hand, as shown in Fig. 1(d) of the supplementary data, the roughness can be reduced to only 5 nm by the method of the present invention, that is, by polishing a diamond (100) substrate in the range of 1.5 to 6 degrees, and hydrogen plasma treating said substrate. Such result would not have been predicted based on the disclosure of the cited references, individually or in proper combination.

Also, it is seen from Fig. 1(d) that this substrate surface is formed as a series of steps of each monoatomic layer. By the gas-phase growth method using this substrate, diamond thin film grows with the carbon atoms supplied from the gas-phase to the side wall of this step, or to a kink formed on the side wall of this step, combining one by one, thereby each step growing. This growth mechanism is called step flow growth mechanism, and is the growing method for the highest crystal perfectness, because random nucleation does not occur and the epitaxial growth is only controlled by the crystal ordering of the substrate. On the other hand, the surface with tilting and polishing only has very large surface roughness, as shown in Fig. 1(a), and also is not formed as a series of steps of each monoatomic layer. Therefore, the step flow growth mechanism does not take place, and since the growth is by other mechanisms than the step flow growth mechanism, the diamond thin film thus obtained has lower crystal perfectness compared with the step flow growth mechanism.

Applicants note that the examiner concluded that the present claims are not unobvious over the cited reference because the method is known in prior arts to grow the S-doped n-type diamond on diamond (100) substrate by microwave plasma CVD method, it is also known that S-doped n -type diamond with high crystallinity can be obtained in this method by having diamond (100) substrate as tilting substrate, and also since the method is known to deposit diamond thin film after hydrogen plasma treating the diamond surface.

The Examiner also concluded that the present application has no inventive step since the methods of the present application, that is, microwave plasma CVD method, tilted substrate, and hydrogen plasma treating are all included in prior arts, though the characteristics of the present application, that is, that of growth on the diamond substrate with steps on the order of monoatomic layer is not explicitly shown in prior arts, it would be realized by combination of these prior arts.

However, the hydrogen plasma treating of Jin et al. is that of diamond substrate surface on which diamond powder with face orientation unknown is pasted on said substrate with face orientation relative to substrate at random. Even by hydrogen plasma treating such substrate, it would be impossible to form the diamond substrate with steps of monoatomic layer order of the present application. As mentioned in the claims of the present application, it can be realized only by polishing a diamond (100) substrate in the range of 1.5 to 6 degrees, and hydrogen plasma treating the substrate.

The cited reference concerning hydrogen plasma treating states it is supposed that contaminant and amorphous carbon are removed from the diamond powder surface by hydrogen plasma treating, the diamond surface is made to possess the negative electron affinity due to hydrogen termination, and also lattice defects are introduced into diamond.

However, Applicants submit that there is no suggestion that the diamond substrate with steps of monoatomic layer order is formed; therefore, even persons skilled in the art would not have learned that the diamond substrate with steps of monoatomic layer order can be formed by hydrogen plasma treating from this description.

JP '994 states that it is difficult to polish a zero degree (111) or (100) face, but easy to polish a tilted face of within 8 degrees of zero, and the crystallinity from tilting within 8 degrees of zero is equivalent to the substrate without tilting, or at least not diminished in such a small range.

However, the present application discloses that the diamond of higher crystallinity can be obtained by tilting within the very specific range of 1.5 to 6 degrees and subsequent plasma treatment, which is not predictable and therefore unexpected in light of the cited reference.

As is shown in Fig. 1(a) of the supplementary data submitted with the Declaration, the surface that was only tilted and polished has the roughness of about 20 nm. This result agrees with the result of surface roughness of diamond thin film after growth of Table 1 in JP '994. On the other hand, as shown in Fig. 1(d) of the supplementary data, the roughness can be reduced to only 5 nm by the method of the present invention, that is, by polishing a diamond (100) substrate in the range of 1.5 to 6 degrees, and hydrogen plasma treating said substrate. Also, it is seen from Fig. 1(d) that this substrate surface is formed as a series of steps of each monoatomic layer. By the gas-phase growth method using this substrate, diamond thin film grows with the carbon

atoms supplied from the gas-phase to the side wall of this step, or to a kink formed on the side wall of this step, combining one by one, thereby each step growing. This growth mechanism is called step flow growth mechanism, and is the growing method for the highest crystal perfectness. On the other hand, the surface with tilting and polishing only is not formed as a series of steps of each monoatomic layer, as shown in Fig. 1(a). Therefore, the step flow growth mechanism does not take place, and since the thin film growth is by other mechanisms than the step flow growth mechanism, the diamond thin film thus obtained has lower crystal perfectness compared with the step flow growth mechanism.

The present application discloses that a series of steps of each monoatomic layer is realized by polishing a diamond (100) substrate in the range of 1.5 to 6 degrees, and hydrogen plasma treating said substrate, thereby the diamond thin film of quite high crystal perfectness can be obtained, and it is presumed from this disclosure that the growth of diamond thin film is realized by step flow growth mechanism.

According to the method disclosed in the present application, it is proved that the crystal perfectness so far not attained can be obtained from the fact that the donor level of the S-doped n-type diamond of this application is 0.38 eV.

TABLE III of page 14344 of "Molecular-orbital theory of monatomic and diatomic substitutional defects as shallow n-type dopants in diamond" (Alfred B Anderson and Emilia J.) Physical Review B vol. 54, No. 20 (1996) pp. 14341-14348, which is attached to this Response, shows the value of theoretically calculated donor level in case that a carbon atom in diamond lattice is substituted with S atom, and the value is 0.37 eV. Since this value is quite close to the donor level 0.38 eV observed in the present application, it is proved that the S-doped n-type diamond of the present application is located at the position of diamond lattice.

As far as the present inventors know, the cited references either do not mention donor level or report the value largely different from 0.38 eV.

None of the references cited by the Examiner report donor level. Applicants note that a person skilled in the art would disclose donor level upon disclosure of his technology concerning doped semiconductor. The fact that donor level is not disclosed in spite of this fundamental premise is believed to show either donor level largely different from the theoretical value was obtained or no reproducible value of donor level was obtained.

That is, Applicants believe that the above indicates that donor level of 0.38 eV has not been realized before the present invention, and it was for the first time realized by the method of the present invention. Thus, it is proved, though indirectly, that, by the method of the present invention, the S-doped n-type diamond with the crystal perfectness that has so far not been attained by prior arts.

Thus, both the n-type diamond made by the method of the present application and the method are novel and unobvious, and therefore should be held allowable.

In view of the aforementioned amendments and accompanying remarks, Applicants submit that that the claims, as herein amended, are in condition for allowance. Applicants request such action at an early date.

If the Examiner believes that this application is not now in condition for allowance, the Examiner is requested to contact Applicants' undersigned attorney to arrange for an interview to expedite the disposition of this case.

If this paper is not timely filed, Applicants respectfully petition for an appropriate extension of time. The fees for such an extension or any other fees that may be due with respect to this paper may be charged to Deposit Account No. 50-2866.

Respectfully submitted,

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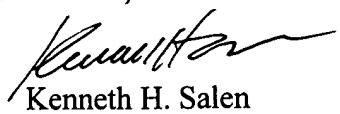

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Enclosures: Inventor's Declaration under 37 C.F.R. §1.132
Reference Figures and Explanation
"Molecular-orbital theory of monatomic and diatomic substitutional defects as shallow n-type dopants in diamond" (Alfred B Anderson and Emilia J.) Physical Review B vol. 54, No. 20 (1996) pp. 14341-14348

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## REFERENCE FIGURES AND ITS EXPLANATION

Reference Fig.1:

Reference Fig.1 shows the implementation result of the smoothing treatment according to this application, which comprises a treatment of exposing the inclined polishing substrate to the hydrogen plasma, thereby to make even the substrate surface to consist of steps each in the order of an atomic layer.

These implementation results were obtained, by AFM(inter-atomic force microscope measurement), the measured AFM values over the entire surface were reconstructed into the graphics which can be able to recognize the surface evenness visually, and the measured AFM values were also re-arranged to the height histogram for comparing evenness. The diamond substrate used for the measure was (100) face oriented substrate, and the substrate was mechanically polished being inclined at an angle about 4 degrees with respect to its <100> direction in a plane made by its <100> and <010> directions. The hydrogen plasma consisted of microwave power of 500W, substrate temperature of 830° C, and hydrogen pressure of 40 Torr.

Fig.1-(a) shows the graphics and the height histogram obtained from the diamond surface which is mechanically polished being inclined as above mentioned. It is clearly seen from this graphics that this surface has the big up-and-down with long cycle, and the big up-and-down

further has the small up-and-down with short cycle. It is also known from this histogram that this surface has unevenness of about 20nm.
This means that nm order unevenness of the diamond surface can no be obtained only by the inclined mechanical polishing.

Fig.1-(b) shows the graphics and the height histogram obtained from the diamond surface which is subjected to the hydrogen plasma for 30 minutes after the inclined mechanical polishing. It is clearly seen from the g raphics and the histogram that the small up-and-down with short cycle has diminished and the surface is more even than the surface of Fig.1-(a).

Fig.1-(c) shows the graphics and the height histogram obtained from the diamond surface which is subjected to the hydrogen plasma for 60 minutes after the inclined mechanical polishing. It is clearly seen from the g raphics and the histogram that the large up-and-down with long cycle has been diminishing and the surface is more even than the surface of Fig.1-(b).

Fig.1-(d) shows the graphics and the height histogram obtained from the diamond surface which is subjected to the hydrogen plasma for 120 minutes after the inclined mechanical polishing. In this graphics, the line of the direction which goes to the upper right from the lower left is the step of an atomic layer. It is clearly seen from the graphics that the steps consisted of each in the order of an

atomic layer has been formed stepped from the lower right of the graphics toward the upper left of the graphics. It is also clearly seen from the histogram that the unevenness is within 2nm.

As indicated in the reference Fig.1, the treatment of exposing the substrate to the hydrogen plasma is for making even substrate surface to consist of steps each in the order of an atomic layer, and not for the surface cleaning cited by the reference of Jin et al.